

THE APPLICATION OF COMPUTERIZED ISOKINETIC FUNCTION
AND MEASUREMENT TO PHYSICAL EDUCATION INSTRUCTION

BY

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In the Name of "God"
Most Gracious, Most Merciful

Dedicated to

My

Mother, Brothers, Sisters

My

Wife and my children:
Safa, Wael, and Wafa.

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by

Mustafa A. J. Hayat

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Abstract of Dissertation Presented to the Graduate School
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THE APPLICATION OF COMPUTERIZED ISOKINETIC FUNCTION
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By

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In recent years the isokinetic dynamometer has become an indispensable clinical, instructional, and research tool. It offers the researcher and the practitioner an accurate and reliable means of assessing the preinjury function of specific muscle groups, as well as the extent of postinjury dysfunction. It can also be used to monitor progress during training and rehabilitation programs.

The purpose of this study was to apply computerized isokinetic function and measurement to physical education instruction.

The major research objective of this study was to compare the right and left legs of normal college age subjects for peak torque generated during extension and flexion at three functional speeds.

The subjects for this study were selected from the students enrolled in the Spring term at the University of Florida. The data were obtained from 50 male and female (25 of each) subjects, ranging in age from 18 to 29 years with a mean age of 22.38 years.

Peak torque data were obtained from subjects' right and left legs during extension and flexion at three speeds; i.e., 60°/second, 180°/second, and 240°/second, as measured by the computerized isokinetic dynamometer.

A randomized block design analysis of variance (ANOVA) was calculated by using an IBM 360 computer and the SPSSP statistical package. A 2 (right and left) x 3 (speed) x 50 (subject) design was used. Significance was accepted at the $p < .05$ level.

The results of the study showed the peak torque generated by the dominant (stronger) leg was significantly greater ($p < .05$) than that generated by the nondominant (weaker) leg at 60°, 180°, and 240°/second. When the subjects' test results were classified by right and left legs, there was no significant differences ($p < .05$) between the mean scores.

Based on the results of this study, it is recommended that physical education instructional programs include content regarding the practice of using the uninjured leg as a model during rehabilitation. In addition, the suggested definition of the terms preferred and dominant in reference to the legs should also be included.

CHAPTER I INTRODUCTION

There are many resistive exercise techniques and devices which have been designed to measure, develop, maintain, or rehabilitate muscle function. Each is based, to some degree, on isometric, isotonic, or isokinetic theory of muscle contraction. For many years these theories have provided researchers and physical educators with a variety of principles which support the study and teaching of human movement.

In this study, the investigator has selected a computerized, isokinetic instrument to measure the peak torque generated during extension and flexion of the leg. It is a training and testing device which monitors the muscle force applied to an accommodating resistance at a constant angular velocity (Clark, 1973). This instrument was chosen for its degree of accuracy, its ability to isolate specific muscle groups, its functional versatility, and its extensive use as a research tool.

The investigator learned to operate the computerized isokinetic dynamometer by working closely with a certified athletic trainer. In addition, he attended a workshop sponsored by the Cybex Company in Orlando, Florida.

The original theoretical basis for the isokinetic exercise dynamometer was expressed by Singh and Karpovich (1956). The first isokinetic exercise device was developed during the early 1960s by Perrine (Perrine & Hislop, 1967). In 1967 the device was used for research purposes by Thistle, Hislop, Moffroid and Lowman and by Perrine and Hislop. In 1969, Moffroid, Whipple, Hofkosh, Lowman and Thistle established the validity and reliability of the device for measuring torque, work, and power of the muscle groups required for specific sports and activities.

In recent years the isokinetic dynamometer has become an indispensable clinical, instructional, and research tool. It offers the researcher and the practitioner an accurate and reliable means of assessing the preinjury function of specific muscle groups, as well as the extent of postinjury dysfunction. It can also be used to monitor progress during training and rehabilitation programs. In addition, it has been found to be a useful instructional device.

Statement of Purpose

The purpose of this study was to apply computerized isokinetic functions and measurements to physical education instruction.

The investigation was designed to include two major sections. First a research study was conducted regarding the function of the knee and second, the elements of the

research were applied to an instructional plan in physical education.

The methods and procedures utilized in the study are described in Chapter III. The study results are reported in Chapter IV. Application of the results in physical education instruction are described in Chapter V with a discussion of each of the following:

1. The development of a training regimen that maintains equity between the strength of the legs.
2. The establishment of a preparticipation and preinjury testing protocol that provides baseline data for comparison with results of tests conducted during and at the completion of training and rehabilitation programs.
3. The development of instructional programs related to the use of the isokinetic dynamometer for clinical, instructional, and research purposes.
4. The establishment of a criterion reference by which the optimum level of rehabilitation of an injured knee joint can be judged objectively.

In order to take part in the educational experiences described above, the investigator conducted the study presented in Chapters I-IV of this dissertation.

The research objective of this study was to compare the right and left legs of normal college age subjects for peak torque generated during extension and flexion at 60°, 180°, and 240°/second. These comparisons were made in an attempt

to determine if preparticipation or preinjury differences existed between the preferred leg and the nonpreferred leg; the dominant or stronger leg and nondominant or weaker leg; and the right leg and the left leg.

It is generally accepted that the knee is the most vulnerable joint in the body related to sports injury. It is for this reason the investigator chose the knee as the primary research focus of this study.

Justification for the Study

In current clinical and instructional settings, physical education, orthopedic surgeons, physical therapists, and other medical professionals are utilizing the uninjured limb as a model or criterion reference in the rehabilitation process. In order to validate this practice the investigator believed it would be necessary to determine if preinjury difference existed between limbs. If such differences were found to be present, serious questions would be raised as to the feasibility of such a practice.

The ambivalence of the research findings in this area of investigation lends additional support for the need for a study of this type. The examples that follow typify the conflicting results found in the literature on this topic.

Goslin and Charteris (1979) conducted a study designed to describe standard positioning techniques employed in isokinetic evaluation and to present normative isokinetic dynamometer data.

Thirty male and 30 female adult volunteers were tested on the Cybex II dynamometer at the speed of 30°/second for knee extension and flexion. The torque, work, and power responses indicated no differences between right and left limbs. However, the dominant or most frequently used limb showed significantly greater responses than the nondominant limb.

In contrast to the Goslin and Charteris (1979) findings, Costain and Williams (1984) found that there is no significant difference between the dominant and nondominant leg for either extension or flexion torque at fast or slow speeds. Wyatt and Edwards (1981) found a significant difference between the dominant and nondominant leg in males but no significant difference for females. Holmes and Alderink (1984) found no age effect on peak torque and no significant differences in peak torques between the dominant and nondominant limb.

This brief review of the literature reflects the contrasting results generally reported in this area of study. However, unlike the present study, many prior investigation treated this topic as a secondary part of a larger study, and therefore did not afford the topic the significances this investigator feels it deserves. In addition, many of these studies were conducted using isokinetic dynamometers that were not as accurate and reliable as the computerized version utilized in this study.

Finally, the ultimate justification for conducting a study of this type were to provide medical professionals, physical educators, athletic trainers, and participants with scientific information which would assist them in (a) reducing the chance of injury or reinjury to the knee joint, as well as (b) increasing the potential for improved performance.

Null Hypotheses for the Study

In statistically analyzing the data collected for this study an attempt was made to support the six stated hypotheses. Each hypothesis was examined as it related to three predesignated categories of comparison of the legs (a) preferred vs. nonpreferred, (b) dominant vs. nondominant, and (c) right vs. left.

The null hypotheses for this study are as follows:

1. There will be no significant difference between mean strength of subjects' two legs as measured by peak torque generated during the extension phase at 60°/second:
 - a. preferred vs. nonpreferred,
 - b. dominant vs. nondominant,
 - c. right vs. left.

2. There will be no significant difference between mean strength of subjects' two legs as measured by peak torque generated during the flexion phase at $60^{\circ}/\text{second}$:

- a. preferred vs. nonpreferred,
- c. dominant vs. nondominant,
- d. right vs. left.

3. There will be no significant difference between mean strength of subjects' two legs as measured by peak torque generated during the extension phase at $180^{\circ}/\text{second}$:

- a. preferred vs. nonpreferred,
- b. dominant vs. nondominant,
- c. right vs. left.

4. There will be no significant difference between mean strength of subjects' two legs as measured by peak torque generated during the flexion phase at $180^{\circ}/\text{second}$:

- a. preferred vs. nonpreferred,
- c. dominant vs. nondominant,
- d. right vs. left.

5. There will be no significant difference between mean strength of subjects' two legs as measured by peak torque generated during the extension phase at $240^{\circ}/\text{second}$:

- a. preferred vs. nonpreferred,
- b. dominant vs. nondominant,
- c. right vs. left.

6. There will be no significant difference between mean strength of subjects' two legs as measured by peak torque generated during the flexion phase at $240^{\circ}/\text{second}$:

- a. preferred vs. nonpreferred,
- c. dominant vs. nondominant,
- d. right vs. left.

Delimitations of the Study

1. The subjects in the study were limited to 50 male and female (25 each) college students ranging in ages from 18 to 29 years.

2. This study was restricted to healthy volunteers with no previous history of any hip, knee, ankle, or back dysfunction. In addition, subjects were asked to report to the test site in a rested state.

3. Testing consisted of knee extension and knee flexion on the computerized isokinetic Cybex II dynamometer at three speeds; low ($60^{\circ}/\text{second}$), moderate ($180^{\circ}/\text{second}$), and high ($240^{\circ}/\text{second}$).

Limitations of the Study

1. The sample population for this study was not drawn randomly from the total population. Therefore, it would be inappropriate to generalize the findings to the total population.

2. There is a small error factor which cannot be controlled when using the isokinetic dynamometer to test knee extension and flexion. This will be accounted for in reporting the results.

3. Time of testing may vary among subjects due to the availability of the testing equipment and subject's schedule. This problem should be minimized by using rested subjects.

4. A subject may work at less than maximum effort which could create inconsistencies in his or her data. To overcome this problem the investigator orally encouraged each subject to give his or her best effort during the test.

Definition of Terms

Dominant leg refers to the stronger leg.

Dynamic exercise refers to exercise that changes muscle tension throughout the joint movement.

Force refers to the exertion on a mass which causes it to accelerate.

Isokinetic exercise refers to strength exercise in which the muscle contraction is performed on a specially designed device at a constant velocity and at an accommodating resistance through a complete range of motion.

Isometric exercise refers to strength exercise in which the muscle applies force to an immovable object thus not changing the length or angle at the joint.

Isotonic exercise refers to strength exercise which involves shortening and lengthening of the muscle while the resistance remains constant and the speed of movement is variable.

Nondominant leg refers to the weaker leg.

Normal college age subject refers to individuals (enrolled Spring 1985) with no prior knee, hip, ankle, or back dysfunction that could impact on the subject's test results.

Peak torque refers to maximum force generated as indicated by the computer and the pen recorder tracking produced by the Cybex II dynamometer. It is expressed in foot-pounds.

Power refers to the rate of doing work.

Preferred leg refers to the participant's leg of choice during volitional performance.

Range of Motion refers to the degree of knee extension and flexion that occurs while the thigh is secured by a thigh strap and the foot is secured to the foot attachment of the Cybex II device.

Static exercise refers to exercise which neither shortens nor lengthens the muscle.

Strength refers to the tension-building capacity of muscle (Perrine, 1968). The maximal force that can be achieved in one repetition at peak resistance.

Torque refers to the force which acts about the axis of rotation.

Weight training refers to the physical activity which involves the use of resistance (barbells, dumbbells, and pulleys) for conditioning and change of the size of various muscles of the body.

Work refers to the force acting through a distance.

CHAPTER II REVIEW OF THE LITERATURE

Validity and Reliability of the Isokinetic Dynamometer

Recently, attention has been directed toward isokinetic exercise, or accommodating resistance exercise, as a means of overcoming the limitations of both isotonic and isometric exercise. Wyatt and Edwards (1981) reported two unique advantages of isokinetic exercise:

First, the angular velocity of an isokinetic device can be specified, and second, when a specified velocity is reached, the device automatically accommodates to give maximal resistance at each point in the range of motion. This allows the specified velocity to be maintained. The device always allows the muscle to work at a maximal level for all points in the range of motion. (p. 48)

Smith (1983) stated two other advantages of using isokinetic exercise as a new dimension in the field of weight training and rehabilitation programs:

(1) All three muscle functions--strength, power, and endurance--can be evaluated easily with one apparatus, (2) muscle function can be evaluated at speeds close to those encountered in athletics, which is the level at which the athlete wants to gain improvement. (p. 43)

The original principle of the isokinetic exercise dynamometer was expressed by Singh and Karpovich (1956). The isokinetic exercise device was developed during the

early 1960s by Perrine, a bio-engineering consultant residing in New York (Clark, 1973; Grimby, 1982; Perrine & Hislop, 1967).

In 1967, the first methodical aspects of the isokinetic dynamometer device were introduced by two research teams, Thistle, Hislop, Moffroid and Lowman; and Perrine and Hislop. It was used as a training and testing device which measured the movement of the muscle force developed through an entire range of motion by accommodating resistance at a constant angular velocity.

Several studies have been conducted to test and determine the reliability and validity of the device. It was used to measure muscle function (strength, power, and endurance) by controlling various parameters such as torque, work, range of motion, and power. Isokinetic exercise was employed to establish norms and evaluate the effectiveness of exercise in increasing muscle strength (Falkel, 1979).

Moffroid and associates (1969) established the validity and reliability of the isokinetic device for measuring torque, work and power under a condition of constant velocity. This was true of many of the larger muscle groups at a wide range of speeds and joint angles. Many corresponded to the movements found in a specific sport or activity. In addition it was shown that torque values measured by the Cybex II dynamometer produced a test-retest coefficient of reliability of $r = 0.995$ ($n = 70$). The same group of researchers determined that the coefficient of validity from

the resulting force was $r = 0.999$. The validity for work measurements at controlled speeds was $r = 0.945$. Finally, they reported values for constant velocity of $r = 0.987$ ($n = 34$).

These high values of validity and reliability were later confirmed by Thorstensson (1976) and documented in many studies (Hart, Barber & Davis, 1981; Johnson & Siegel, 1978; Laird & Rozier, 1979; Lesmes, Costill, Coyle & Fink, 1978; Rankin & Thompson, 1983). To further support the use of isokinetic principles in studying velocity in relation to the human musculo-skeletal system Alexander and Molnar (1973), Goslin and Charteris (1979), Ostering (1975), Richard (1981), Rogers (1984) also reported positive results.

Johnson and Siegel (1978) estimated the reliability of an isokinetic exercise using Cybex II dynamometers for the knee extensor over a given number of trials and days. The coefficient of reliability was quite high, ranging from 0.93 to 0.99.

Parker (1982) determined the validity of a new method which provides a calculation of the isokinetic speed of knee rehabilitation as ($r = 0.98$; $r = 0.94$) in the excellent range as revealed by the high correlation between predicted and observed measurements of quadriceps torque during true and quasi conditions of rehabilitation.

Rogers (1984) conducted an investigation to determine the reliability of using a Cybex II isokinetic device in the

neck strength measurement of 54 football players. The athletes were given three trials of right and left rotation. The results reported showed a reliability coefficient of .88.

Barbee (1984) conducted an investigation to determine the reliability of Cybex computer measures of peak torque, torque deceleration energy, work, and power. Knee flexion and extension were tested at speeds of 60, 180, and 300 degrees per second. The researchers found that correlation coefficients for right and left leg measurements of quadriceps and hamstrings at all speeds were as follows:

(1) Peak torque ranged from .91 to .97; (2) power measured in watts ranged from .86 to .95; (3) - total work ranged from .85 to .97. Torque acceleration energy for the quadriceps at 50 degrees per second ranged from .13 to .27, and from .75 to .86 for hamstring measurements at 60 degrees per second. For the quadricep and hamstring measures at 180 and 300 degrees per second, values ranged from .86 to .98. (p. 735)

Comparison of Strength Training Modes

Moffroid et al. (1969) reported the usefulness of isokinetic exercise based on norms established by testing the quadricep and hamstring muscles of normal young adult subjects:

(1) Isokinetic exercise is an effective means of increasing muscular torque throughout an arc of motion; (2) isokinetic exercise increases the work a muscle can do more rapidly than does isometric exercise or isotonic exercise using pulleys, (3) muscular response to different loading systems tend to be specific; that is, a muscle which is overloaded in a partial range of motion will increase significantly more in that range than in other, less exercised positions. (p. 746).

The majority of studies which have been conducted in the past two decades dealt with comparison on three modes of strength training (isometric, isotonic, and isokinetic exercise). Researchers, therapists, coaches, and trainers attest to the superiority of exercising and testing muscle strength isokinetically in lieu of both isotonic and isometric methods, (Hinson & Rosentswieg, 1972; Knapik & Ramos, 1980; Knapik, Wright, Mawdsley & Braun, 1983; Moffroid et al., 1969; Pipes & Wilmore, 1976; Van Oteghen, 1975; Wilmore, 1977).

Thistle and associates (1967) reported the results of a pilot clinical study comparing the torque generated by three experimental groups, an isometric, an isotonic, and an isokinetic strength group. Sixty normal subjects were divided equally into three exercising groups. The results indicated that after eight weeks (four days per week) the group which trained isokinetically demonstrated higher increases in exertion of peak force ability than the group trained isotonicly. It was also shown that the isokinetic training group was significantly better than both the other groups. It gained 35.1 foot-pounds in total work, while the isotonic and isometric group gained 27.5 foot-pounds and 9.4 foot-pounds, respectively. Similar studies conducted by Moffroid et al. (1969) with quadricep and hamstring muscles showed, after four weeks training, that the three groups made significant gains in strength in the quadricep muscles when they were tested isometrically at 90 degrees. However,

only the isometric group gained significantly in strength when the groups were tested at the same speed and the same angle for hamstring muscles, but when the groups were tested at an angle of 45 degrees, both the isokinetic and isometric groups were significantly improved. When the groups were tested for isokinetic work, none of the groups improved significantly in the quadriceps, but the isokinetic group was significantly better when the hamstrings were tested (Clark, 1973).

Hinson and Rosentswieg (1972) compared the three ways of developing muscle strength. The results indicate that the isokinetic exercise caused significantly more electrical activity than either the isotonic or isometric exercise. This research team has recommended that the isokinetic method be utilized by those interested in strength gain. They also found the isokinetic method to be simple, challenging, fast, and likely to produce the best results in a limited time.

Pipes and Wilmore (1975) conducted a study designed to compare the effectiveness of a group trained isokinetically with another group trained isotonically in producing changes in strength, body composition, anthropometric measurements, and selected motor performance tasks. Thirty-six adult men, aged 20-38, were randomly assigned to one of four groups: (a) isotonic, (b) isokinetic low speed contraction, (c) isokinetic high speed contraction, and (d) a control group. Strength training was conducted 40 minutes a day,

three times a week for a period of eight weeks. The results demonstrated a clear superiority of the isokinetic high speed training over isotonic exercise relative to strength, anthropometric measures, and motor performance tasks. Each of the training groups exhibited similar changes in body composition. The isokinetic high speed group demonstrated the greatest gains overall (Counsleman, 1976). Similar results were reported by Van Oteghen (1975) who found that slow and fast speed isokinetic groups were significantly better than the control group on vertical jump performance, and that the slow speed isokinetic group also improved significantly more in strength gain than the control group. Van Oteghen suggested that greater increases occur early in the training program as compared to those increases which occur later.

In another study, Lesmes, Costill, Coyle and Fink (1978) reported the results of their study as follows:

(1) Isokinetic training programs of 60 and 30 seconds duration can significantly increase peak muscle torque, (2) training velocity may be an important consideration in improving peak torque, (3) total work output was increased an average of 30% with either training at relatively slow (60° per second) or fast (180° per second) velocities, (4) both training programs significantly reduced the fatigue level of both the knee extensor muscles, especially in the leg trained with 30 second workouts. (p. 266)

In comparing the two dynamic training programs, isotonic and isokinetic exercise, Steven (1980) conducted a study to determine if either isokinetic or isotonic training affects the development of lower body strength and power. A

random sampling of 75 students from an elective weight training class in physical education was divided into three groups. Each group was tested three times during the study. The results showed that the isotonically trained group clearly demonstrated the best achievement in the power test (vertical jump) and the 40-yard dash time. According to Steven (1980), there is a relationship between absolute strength and power. Power always involves a combination of strength and speed, with the particular sport dictating the emphasis on one or the other. Although strength is essential in improving performance, power training meets the demands of the sport more specifically, not only in terms of the required strength level, but in the actual velocity at which the strength is applied.

Smith and Melton (1981) conducted a similar study with variable resistance training at different speeds (low to high). When subjects were tested on quick acceleration, the results showed that the fast isokinetic exercise increased strength and performance levels more efficiently than low speed isokinetic exercise or training in the isotonic resistance mode. Smith and Melton recommended that the concept of training specificity should be used in all training and rehabilitation programs. The patient athlete should be trained in the manner most similar to his actual athletic performance. The researchers also suggest that a complete training rehabilitation program should include exercise to increase strength and power, and also should be

designed to increase the fatigue limit most comparable to the athlete's performance levels.

Knapik and Ramos (1980) found the relationship between isometric and isokinetic strength by testing maximum voluntary contraction of the leg and arm muscles of 352 male soldiers. Knee extension, knee flexion, elbow extension, and elbow flexion were tested isokinetically at 90° and 120° of flexion and isokinetically at speeds of 30° per second, 90° per second, and 180° per second on a Cybex II dynamometer. The results indicated that isokinetic torque declined with increasing velocity of contraction. A high relationship was found between the isometric test and the lower velocity isokinetic test and between the isokinetic velocities that were close together. The researchers suggested that the torque elicited during low-velocities isokinetic contraction can be predictive of torque elicited during isometric contraction. Faster velocities were less related to isometric strength. The investigators believed that the peak torque recorded at isometric and low-velocity contraction may have occurred at a different location in the range of motion than the peak torque recorded at faster velocities.

Otis, Warren and Deland (1981) demonstrated a strong correlation between isometric and isokinetic strength measurement when compared at the same joint position. Otis and his associates suggested that the determination of the normal relationship can provide a norm for conducting the

dynamic performance of muscle independent of absolute strength.

In a study by Knapiket et al. (1983) in which they compared the strength relationships with the three modes of exercising (isotonic, isometric, and isokinetic), torque measurements were obtained from 16 young, healthy men, utilizing the Cybex II dynamometer at speeds of 36° per second, 108° per second, and 180° per second. The investigators suggested that isokinetic strength measures may be predictive of isometric strength at the same joint angle. However, as the joint angle becomes more widely separated, the relationship decreases within the same mode of exercise.

In a more recent study, Bottjen (1984) compared strength changes between isometric and isokinetic exercise on the hip extensor muscle group after a six-week training period. Twenty-five normal subjects were randomly divided into two training groups. The results of the study indicated that the mean increase for the isokinetic group was significant, while that of the isometric group was not.

Most of the studies which have been conducted to determine the relationship between the three modes of strength exercise (isometric, isotonic, and isokinetic) reported isokinetic data at slow speeds of 120° per second or less. Findings from these studies suggested that peak torque occurs later in the range of motion with increasing speeds, (Moffroid et al., 1969; Ostering, 1975; Pipes &

Wilmore, 1976; Scudder, 1980; Sherman, Plyley, Pearson, Habansky, Vogelgesang & Costill, 1983; Sherman, Plyley, Vogelgesang, Costill & Habansky, 1981; Smith & Melton, 1981; Thistle et al., 1967; Van Oteghen, 1975; Watkins & Harris, 1983). Sherman et al. (1983) supported the contention that rehabilitation training programs should include slow, medium, and high speed isokinetic exercise.

The Effects of the Isokinetic Dynamometer

In recent years, many researchers have investigated the area of isokinetic strength exercise utilizing the Cybex II dynamometer. These studies have had great influence in the area of physical therapy, physical medicine, and athletic training for testing and training muscle function (power, strength, endurance) under conditions of constant velocity (Campbell & Glenn 1979; Lesmes et al. 1978; Miyashita & Kanehisa 1979; Murray, Baldwin, Gardner, Sepic & Downs 1977).

Findings from these investigators suggested that the Cybex isokinetic device has been effectively used in determining the peak torque through a full range of motion at a preselected speed during extension and flexion of the joint; the relationship between maximal isometric torque and isokinetic torque at different speeds and angles of flexion; and the determination of the relative torque output at various rates of motion (Moffroid et al., 1969; Perrine &

Hislop, 1967; Rogers, 1984; Scudder, 1980; Sherman et al., 1981).

A large body of information has been gathered in the areas of physical medicine and athletic training in the use of the Cybex II isokinetic dynamometer device. It was obtained as a result of conducting research studies in order to get normative data that could be used for the purpose of improving conditioning programs, preventing and predicting sports injuries through preseason examinations, testing an athlete's performance ability for a specific sport by examining variables related to athletes from different sports, athletes within the same sports, or athletes and nonathletes. The variables included were age, sex, weight, height, and limb dominance, among others (Alexander & Molnar, 1973, 1974; Aniansson, Grimby & Rundgren, 1980; Coleman, 1982; Costain & Williams, 1984; Davies, Gould & Ross, 1982; Goslin & Charteis, 1979; Holmes & Alderink, 1984; Knapik, Jones, Bassman, Harris & Wright, 1982; Miyashita & Kanehisa, 1979; Molnar & Alexander, 1973; Murray et al., 1977; Parker, Holt, Bauman, Draynn & Ruhling, 1982; Rankin & Thompson, 1983; Smith, Quinney, Wenger, Steadward & Sexsmith, 1981; Wilkerson, Martin & Sparks, 1980).

Another body of literature was gathered in the area of physical therapy. Researchers were attempting to find some evidence which could help improve the procedures used in the

treatment and prevention of injuries. Data from these studies were used to make more accurate diagnoses and to develop new rehabilitation techniques' (Campbell & Glenn, 1979; Costill, Fink & Habansky, 1977; Clancy, 1983; Gilliam, Saddy, Freedson & Villanacci, 1979b; Gleim, Gilbert, Nicholas, James & Webb, 1978; Grimby, Gustafsson, Peterson & Penstrom, 1980; Scudder, 1980; Tegner, Lysholm, Gillquist & Oberg, 1984).

Isokinetic Testing of Healthy Boys and Girls

A review of literature related to isokinetic strength testing and exercise demonstrated that the differences in torque values among young healthy boys and girls are affected by age, sex, weight, and height. In order to explore the various growth and development parameters as they relate to muscle function, a young healthy population offers a wide variety of opportunities.

Alexander and Molnar (1973) conducted a study to determine the norms for children to be used in clinical practice. Muscle flexors and extensors were tested bilaterally at the elbow and knee, using the Cybex isokinetic dynamometer. Anthropometric measurements were determined and their correlation with muscle strength was examined in 38 boys and girls from 7 to 15 years of age. The result indicated that the mean values of muscle strength scores were greater for boys than for girls. They also reported

correlation of $r = .89$, $r = .92$, and $r = .79$ between torque for the left knee extensor (at a speed of 30° per second) vs. age, height, and weight. Replicating this study, the same investigators (1974) examined a larger sample, 500 healthy boys and girls. The results determined a normative value of quantitative muscle strength related to age, weight, and height of subjects. It also showed a multiple correlation value of $r = .86$ for knee extensors (foot-pounds) with age, height and weight for boys and girls. These results also indicated that the isokinetic testing and exercising device can be applied to obtain strength determination for selected muscle groups.

Gilliam, Villanacci, Freedson and Sady (1979a) reported that torque values at a speed of 120 per second indicated that significant sex differences were present in the knee extensor and flexor scores based on the body weight of 28 healthy boys and 28 healthy girls, aged 7 to 13 years. The boys generated 29.2 and 39.5 foot-pounds while the girls generated 26.2 and 35.4 foot-pounds for knee extension and flexion.

Miyashita and Kanehisa (1979) tested a large group (569) of healthy boys and girls, age 13 to 17 years, and 35 swimmers age 11 to 21 years. The results showed a linear increase in isokinetic knee extensor muscle strength for boys age 13 to 17 years, while it remained relatively constant for girls age 13 and 14 years. The swimmers' peak

torque for the knee extensor muscle was very similar to the value obtained for the other boys and girls of the same age. It was concluded that males can produce greater torque values than females.

Isokinetic Testing of Healthy Adults

In evaluating other studies of isokinetic strength exercise in the knee extensor and flexor muscles, this investigator found that many researchers reported on maximum torque values at different angles generated by healthy adult subjects.

Murray, Gardner, Mollinger and Sepic (1980) used the Cybex II isokinetic dynamometer to determine standards of knee extensor and flexor muscle performance in two groups, 20-35 years old and 45-65 years old. The results showed that the mean extensor muscle torque was higher than the mean flexor muscle torque in both groups, and the mean torque for extensor and flexor muscles was higher among the younger group than the older group. In a similar study, Murray et al. (1977) reported that the strength of a group of older men, 70-88, was significantly less than that of younger groups of 20-35 and 50-65. In addition, they found that the men in the oldest group generally took longer than the younger men to reach peak torque during isokinetic contraction.

Aniansson, Grimby and Rundgren (1980) conducted a study to determine normative data on isokinetic and isometric muscle strength for an older, healthy population (70 years of age). Right knee extension and maximal extension velocity of 40 men and 32 women was obtained by using the Cybex dynamometer. The results indicated that the maximal extension velocity of the knee was similar in men and women. It is also reported that all isometric and isokinetic peak torque values were higher for men than women. Aniansson and his co-workers also found an inverse correlation between muscle strength and previous physical occupational activity in men over 40 years of age. They suggested that the decline in strength in older people was caused by change in fiber size in the neuromuscular system, in contralcal proteins, and protein metabolism. Johnson (1982) reported also that the younger subjects have higher torque outputs, both isometrically and dynamically, than the older subjects.

The Isokinetic Dynamometer and Clinical Research

In the area of clinical research the majority of the studies reviewed focused on unilateral muscle pathology and muscle strength deficits. By employing a Cybex strength testing and exercise device researchers were able to determine the effectiveness of many treatment methods and rehabilitation techniques on muscle function.

The peak torque output generated by an involved limb and an uninvolved limb was used as the key measure to determine muscle strength deficits of athlete and patient populations. These data were used to determine the probability of injury and to make decisions regarding when to return athletes to competition and nonathletes to their daily activities.

In other patient studies investigators used ratios of muscle strength in order to compare the weaker muscle groups to stronger muscle groups in order to determine the effectiveness of treatment and rehabilitation techniques on muscle strength. Burkett (1970) reported that there is a correlation between muscle strength imbalance and the increased incidents of hamstring muscle strain. One group of 30 high school track athletes were evaluated retrospectively and a second group of 37 professional football players were examined for muscle imbalance between the hamstrings and decreased flexibility. The results showed that a 10% or greater strength deficit between right and left hamstring muscles was considered to be a predictor of the eventual occurrence of hamstring strain.

Merrifield and Cowan (1973) conducted a study to determine the percentage of torque output difference between the injured knee and the healthy knee by using the Cybex isokinetic dynamometer. At the beginning of a season, 54 high school and college ice hockey players were tested for the

relative strength of the thigh muscles of each leg. The results indicated that all injured players who were tested showed a force and power imbalance between thigh muscles of at least 25%. According to Merrifield and Cowan (1973) this finding was the best single predictor of a potential muscle strain injury. This was significantly different from the finding related to noninjured players.

According to Elliott (1978),

when comparing the injured leg with the uninjured one, the key measurement is the peak torque force that can be generated by each limb. Peak torque is measured on the Cybex at slow, moderate, or high speeds. (p. 2408)

If strength difference is found between the two limbs are found to be greater than 10% there is an increased chance of injury.

Campbell and Glenn (1979) used the Cybex isokinetic dynamometer in testing the torque of the knee extensors and knee flexors of eight rehabilitated patients who had menisectomies. The tests were conducted at speeds of 60° per second and 210° per second. The results indicated a 10% to 12% deficit in the rehabilitated knee when compared to the uninjured knee five to 15 months after the operation.

In pretesting athletes, Hunter, Cain and Henry (1979) measured strength levels of the knee joint using a Cybex isokinetic dynamometer. The results showed that the healthy left knee had a quadricep peak torque of 258 foot-pounds and a hamstring peak torque of 138 foot-pounds. They also found the right post-menisectomy knee to have a maximum torque of

156 foot-pounds and a hamstring maximum torque of 150 foot pounds. This result indicated that the right quadricep produced only 51%* as much torque as the left, while the right hamstring produced over 100% of the left. This points to the need for more emphasis on quadricep rehabilitation.

Paulos, Noyes, Grood and Butler (1981), recommended that the patient reach at least 75% of normal leg strength and power before returning to normal activity.

Richard (1981) described how the shape and amplitude on the graph, the reproducibility of the torque-angle curves, as well as the torque-velocity relationship in the healthy subject can provide a basis of comparison for the evaluation of muscle dysfunction in patients with various pathologies. "Data from such comparison can be applied by choice and coordinated with various therapeutic procedures including techniques related to muscle strengthening" (p. 149).

Using the Cybex as a rehabilitation tool, Sherman et al. (1981) found the strength of the injured leg, after seven weeks of exercise, to be 30% lower than the nonsurgical leg. At 14 weeks it was essentially normal at 95% of the uninjured leg's strength level (recorded at a speed of 180° per second). This was not statistically different from 100% recovery. Therefore, they suggest that

*This investigator believes this to be in error. It should be 60%.

the surgical leg must achieve 100% recovery at each isokinetic training speed before advancing to the next phase of rehabilitation. The investigators recommended that athletes and patients train at slow, medium, and fast contraction velocities. They suggest that 14 weeks' training on a Cybex isokinetic strength device is enough for an individual with a surgical limb to attain a strength level comparable to that of the nonsurgical limb. Sherman et al. (1981) also recommended that therapists strengthen muscles surrounding a joint which has been affected by injury, surgery, or immobilization to 100% of the healthy limb at all isokinetic training velocities.

In another study, Patel, Fahmy and Sakayan (1982) tested 40 patients who underwent arthroscopic surgery. Using a Cybex for testing and training, the result showed that patients resumed routine activity in a mean of six days, sports activities in ten days, and recreational activity in 18 days. It was also found that the mean quadricep deficits measured at 30° per second were 12% and 11% at 180° per second and the mean hamstring deficits were 4% and 5% respectively.

The Cybex II dynamometer was used by Watkins and Harris (1983) to measure quadricep and hamstring function in 12 patients. The peak torque value of the quadricep of the untreated side was compared with the peak torque value of the quadricep of the treated side. The result indicated

that at 30° per second there was a deficit of 54%, and a 49% deficit at 180° per second.

Odensten, Tegner, Yelverton, Lysholm and Gillquist (1983) found similar results in that the quadriceps in treated legs were significantly weaker than the quadriceps in nonoperated legs when the peak torque values for the legs were compared.

Watkins, Harris, Bette and Rolzowki (1984) reported that the peak torque level of the muscle groups of both the involved and the uninvolved limbs of patients was significantly less than the peak torque level of the muscles of the healthy subjects at both 30° per second and 180° per second.

Sherman et al. (1983) reported that the early release from a rehabilitation program to normal daily activity after a menisectomy with a 15% strength deficit between treated limb and untreated limb, will allow complete recovery. They believed that the 20% deficit in the operated limb as compared with the nonoperated limb will be eliminated as the patient advances through the phases of the rehabilitation program.

Quadricep and Hamstring Ratios

Sutton (1984) stated that an optimal muscle strength balance occurred when hamstring muscle demonstrated 50% to 60% of muscle strength of the quadriceps. Gilliam et al.

(1979b) found only a 2% to 3% difference between the right and left legs on torque measurement. The correlations between the right and left side torque values at speeds of 30° per second and 180° per second exceeded $r = .82$. Gilliam et al. (1979a) found that the ratio between hamstring and quadricep muscles was 60% at a speed of 30° per second and 70% at a speed of 180° per second. However, the torque difference between the extensors and flexors begins to diminish as the speed in degrees increases. In addition, it was found that torque measures differ according to the subject's age and the position the athlete plays in the sport of football.

Results reported by Coplin (1971) indicate a 60% ratio between hamstring and quadriceps was acceptable for normal muscle balance around the knee joint for college-age football players.

Scudder (1980) tested 140 normal male subjects ranging in age from 19 to 29 years on peak torque generated at different rates of motion during the knee extension and flexion. The results showed that the ratio between the hamstrings and quadriceps was 63% at 60° per second. This was also reported by Moffroid et al. (1969).

In addition, Scudder (1980) concluded that the ratio between the hamstrings and quadriceps did not change as the speeds of exercise changed. Wyatt and Edwards (1981) concluded, however, that there is less difference between the

torque output of the muscle groups as the test speed of isokinetic exercise increases and that the ratio approaches unity at 300° per second.

Gilliam et al. (1979a) and Sutton (1984), reported a quadricep and hamstring strength ratio increase in excess of 80% at test speeds of 300° per second.

In other studies, Davies, Kirkendall, Leight, Lui, Reinbold and Wilson (1981) examined 91 professional football players at 45° per second and 180° per second to establish the relationship between hamstrings and quadriceps. The results indicated the ratio between hamstrings and quadriceps to be 60% at 45° per second, and 80% at 180° per second.

Wyatt and Edwards (1981) reported a higher hamstring and quadricep ratio from previous studies at 72% for males and 71% for females (at 60° per second), 78% and 79% respectively (at 180° per second), and 85% and 83% respectively (at 300° per second). It appeared that the ratio of hamstring to quadricep increased with speed.

Wyatt and Edwards (1981) also reported the ratio of nondominant to dominant knee torque value was equal to or greater than 97% in all tests. In addition, these investigators stated that "no study quantifies how large a difference among speeds is necessary to measure a significant change in torque output produced" (p. 54). They

found a speed of 120° per second demonstrates a significant difference in the torque produced.

Strength Comparisons Between the Right and Left Legs

Although studies of the ankle, hip, and elbow have been reported by many investigators, the knee joint and knee muscles (hamstrings and quadriceps) have been the focus of most studies. In reviewing this literature, conflicting results were found in some studies attempting to compare the strength of the right and left, as well as the dominant and the nondominant limbs.

Alexander and Molnar (1973, 1974) and Molnar and Alexander (1973) reported that the dominant leg was stronger in male and female subjects age 7-15 years.

Wyatt and Edwards (1981) found a significant difference between the dominant and nondominant legs for male subjects, but no significant difference for female subjects.

Goslin and Charteris (1979) conducted a study in which 30 male and 30 female young adult volunteers were tested on the Cybex II dynamometer at a speed of 30° per second for knee extension and flexion. The torque, work, and power responses indicated no differences between right and left legs. However, the dominant (strongest) limb showed significantly greater response than the nondominant limb.

In determining the differences in muscle groups, between the right and left legs, Distefano, Nixon, O'Neil

and Davis (1978) found it is impossible to predict the dominant leg on the basis of relative leg strength. Therefore, they discount any theory of leg dominance.

In comparing the right and left legs, Garzione and Merrifield (1979) found that only the hamstrings were significantly different.

Wilkerson, Martin and Sparks (1980) conducted a study to assess leg strength, power, and endurance. Peak torque for knee extensor and flexor muscles of 13 male marathoners was measured by the Cybex isokinetic dynamometer at 30°, 60°, 120°, 180°, 240°, and 300° per second. Ten subjects were right leg dominant and three were left leg dominant. The results indicated that the ratio of right to left scores for both knee extensor and knee flexor muscle groups was constant at 1.0 at all limb speeds. The right leg work output during this 40 second test averaged 96.5 of what was observed for the left leg. In no test was the dominant leg predictable from test scores.

Bailey (1981) used the Cybex isokinetic testing and exercise device in preseason medical examinations of high school football teams to establish "norms" for strength and power for young men between 14 and 18 years of age. The results showed the extensor norms for left legs to be 65.62 and 67.62 for the right leg, flexor norms for the left leg to be 45.62, and 43.58 for the right leg. Bailey also found a significant number of these young athletes had differences

in power and strength of more than 10% when scores for each knee were compared. Bailey stated that

It is quite significant that of 93 high school football players, one out of four had an imbalance of 10% or more between power scores for the quadriceps group at both knees, and one out of three had a 10% or more difference between hamstring groups. (p. 18)

Klafs and Arnheim (1981) also predicted hamstring strain in 30 track and field athletes who had an imbalance of 10% or more between the hamstring muscle groups.

Wyatt and Edwards (1981), Costain and Williams (1984), Holmes and Alderin (1984) and Richard (1981) determined the dominant leg by asking the subjects which leg they would use to kick a ball. Richard reported that the peak extension and flexion values were greater in the nondominant leg.

In a recent study Costain and Williams (1984) found that (a) extension torque is significantly greater than flexion torque for both legs at speeds of 30° per second and 180° per second, (b) there is no significant difference between the dominant and nondominant legs for either extension or flexion torque at fast or slow speeds, (c) at 30° per second, peak quadriceps torque is achieved at approximately 73° of extension and peak flexor torque is achieved at approximately 38° of flexion, and (d) slow speed flexion and extension torque levels are significantly greater than fast speed torque levels for both legs.

Holmes and Alderink (1984) also found no age effect on peak torque and endurance between dominant and nondominant limbs for both males and females.

Barbee (1984) reported no significant difference between the right and left knees related to peak torque, power and work, on the knee extension and knee flexion.

CHAPTER III METHODS AND PROCEDURES

Selection of the Subjects

The subjects for this study were selected from the students enrolled in the spring term at the University of Florida. The data were obtained from 50 male and female subjects, ranging in age from 18 to 29 years with a mean age of 22.38 years.

The number of subjects assigned to each treatment cell was determined by utilizing the tables suggested by Cohen (1977). The values used for entry into the table were as follows: $p = .05$ (level of significance), $u = 1$ ($K-1$), $f = .40$ (value for large effect size), and a power of .80. Based upon the specifications used in this study, a table value of $n = 25$ was obtained as a minimum number for each group. The additional subjects were selected to increase the power of the statistical test.

The data for the male and female subjects were combined for analyses based on the results of a pilot study in which no significant difference ($p = .05$) was found between the mean differences for the right and left legs of the male and female subjects. These findings are supported in the

literature (Goslin & Charteris, 1979; Costain & Williams, 1984).

Type of Data to be Collected

On the day of testing, the subjects completed a subject information sheet to provide a brief medical history. The history noted any injury to the knee, hip, ankle or back. Limb preference was determined by requiring the subject to kick a ball a distance of four to five feet. The condition of the heart and blood pressure was noted. The subject's weight and height were recorded. Strength data were obtained from the subject's right and left leg extension and flexion at three speeds, i.e., 60°/second, 180°/second, and 240°/second (see Appendices E and F).

Instrumentation

A computerized version of the Cybex II (Lumex, Corp., Ronwonkoma, NY) isokinetic dynamometer system and a single channel chart recorder were used in this study to measure muscle strength on both lower extremities of each subject. All Cybex units record torque in foot-pounds (see Figures 1 and 2).

Procedures for Collection of Data

1. Preparation of testing site:

The testing device was adjusted and the electrogoniometer was checked before each subject was tested.



A. Cybex unit



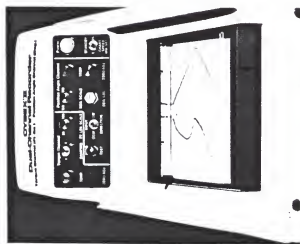
B. Instrumentation units

Figure 1. Cybex and instrumentation units.
(Reprinted by permission)

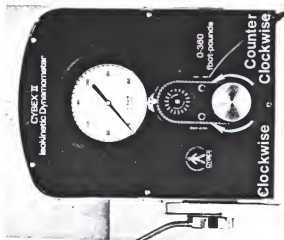
a. Speed selector



b. Data reduction computer



c. Dual-Channel recorder



d. Isokinetic Dynamometer and torque display

Figure 2. Cybex instrumentation units. (Reprinted by permission)

2. Orientation session.

a. Each subject was read a standardized statement regarding isokinetic exercise, the isokinetic device, and the testing procedures.

b. Each subject completed a descriptive questionnaire.

c. Each subject signed an informed consent statement (see Appendices A and B) before being allowed to take part in the study.

d. The subject's weight and height was recorded.

e. The preferred leg was determined by asking the subject to kick a ball a distance of four to five feet.

3. Testing procedures.

a. The subject was seated with the thigh and pelvis strapped against the apparatus. This was done to stabilize the hip joint and the trunk.

b. Subject information (name, date, body weight, leg being tested) and test information was entered into the computer.

c. The recorder power was turned "On." The isokinetic dynamometer was prepared for testing.

d. Before beginning the first test (60° /second) for each side of the body, each subject's limb was positioned at anatomical zero and locked by setting speed selector at "0." The limb was weighed at flexion to negate any effect of gravity on the torque readout.

e. The appropriate zero degree baseline setting was made by turning the goniometer gear dial to position angle of the stylus.

f. An initial warm-up of two or three submaximal contractions was allowed prior to testing at each speed to familiarize the subject with the feel of the accommodating resistance provided by the isokinetic dynamometer.

g. The subject was not allowed to use the handles on either side of the seat to prevent accessory joint movement.

h. Thirty-second rest periods were allowed between warm-up and actual testing.

i. The testing sequence was five repetitions of extension and flexion movement of the leg at 60° /second, chart speed, five repetitions at 180° /second, and 15 repetitions at 240° /second with the chart speed at 5 mm/sec.

j. A three- to four-minute rest was provided for each subject between each testing segment.

k. A four- to five-minute rest was allowed each subject when changing the test position from one limb to the other. During this break the subject was allowed to walk and move about.

l. Strong verbal encouragement was given to facilitate maximum performance by each subject.

Analysis of Data

Mean, standard deviation, range, and absolute differences between legs was calculated at each speed (60°, 180°, and 240°/second) and for each muscle group (quadriceps and hamstrings) for the right and left legs, the preferred and the nonpreferred legs, and the dominant and the nondominant legs (see Appendices C and D).

A randomized block design analysis of variance (ANOVA) was calculated by using an IMB 360 computer and the SPSSP statistical package. A 2 (right and left) x 3 (speed) x 50 (subject) design was used (Kirk, 1968). Significance was accepted at the $p < .05$ level.

CHAPTER IV RESULT AND DISCUSSION

The research objective of this study was to compare the right and left legs of normal college age students for peak torque generated during extension and flexion at three functional speeds. These comparisons were made in an attempt to determine if preparticipation or preinjury differences existed between the preferred leg and the nonpreferred leg; the dominant or stronger leg and the nondominant or weaker leg; and the right leg and the left leg.

An initial examination of the results indicated that 46 of the 50 subjects studied preferred the use of the right leg for kicking a ball. This finding made additional comparisons related to preference unnecessary in each hypothesis, since the right and left legs differences were to be compared.

The means and standard deviations related to the peak torque values for extension and flexion of the dominant and the nondominant legs as well as the right and left legs are presented in Tables 1, 2, 3 and 4.

It can be noted that in Table 1 the mean and standard deviation scores for extension of the dominant leg are greater than those for the nondominant leg at all test speeds.

The results shown in Table 2 are consistent with those in Table 1. Under each test condition the mean and standard deviation scores for flexion of the dominant leg were higher than those reported for the nondominant leg at all speed tested.

The pattern established in Table 1 and 2 is continued for the mean scores reported in Tables 3 and 4. The mean differences were smaller than in Tables 1 and 2; however, in each instance, the right leg mean torque values for both extension and flexion were higher than those found for the left leg.

Table 1

Means and Standard Deviations of Peak Torque (ft-lb)Generated by Extension of the Dominant and Nondominant Legs.

Variables	Mean	SD
Dominant		
60°/second	136.16	38.23
180°/second	88.84	26.55
240°/second	73.34	23.27
Nondominant		
60°/second	121.94	34.60
180°/second	80.48	25.46
240°/second	66.80	23.13

Table 2

Means and Standard Deviations of Peak Torque (ft-lb)Generated by Flexion of the Dominant and Nondominant Legs.

Variables	Mean	SD
Dominant		
60°/second	84.46	25.57
180°/second	63.90	19.68
240°/second	56.26	19.67
Nondominant		
60°/second	76.60	23.05
180°/second	58.26	19.41
240°/second	50.88	18.31

Table 3

Means and Standard Deviations at Peak Torque (ft-lb)Generated by Extension of the Right and Left Legs.

Variables		Mean	SD
Right	60°/second	130.86	39.73
	180°/second	84.34	25.59
	240°/second	70.74	23.05
Left	60°/second	126.52	34.30
	180°/second	83.82	27.25
	240°/second	69.24	23.62

Table 4

Means and Standard Deviations of Peak Torque (ft-lb)Generated by Flexion of the Right and Left Legs.

Variables		Means	SD
Right	60°/second	81.06	25.26
	180°/second	61.38	19.74
	240°/second	53.90	19.70
Left	60°/second	80.00	24.04
	180°/second	60.78	19.77
	240°/second	53.02	18.04

The standard deviation scores reported in Tables 3 and 4 are similar to those reported in Tables 1 and 2, but the pattern was not as consistent.

The mean torque values for each test were analyzed using an analysis of variance (ANOVA) to determine if significant differences existed between the dominant and the nondominant leg, as well as the right leg and the left leg. The calculations were made for both leg extension and flexion at test speeds of 60°, 180°, and 240°/second.

The .05 (*) level of significance was established as the criteria for rejecting or failing to reject the null hypothesis stated in Chapter I of this dissertation. For clarity and convenience, each of the hypotheses are restated and discussed here in the same order as originally presented.

Null Hypothesis 1. There will be no significant difference between mean strength of subjects' two legs as measured by peak torque generated during the extension phase at 60°/second.

- a. preferred vs. nonpreferred (refer to page 44),
- b. dominant vs. nondominant,
- c. right vs. left.

The mean peak torque value of 136.16 (ft-lb) for extension of the dominant leg at a speed of 60°/second was significantly different ($p < .05$) than the mean of 121.94 for the nondominant leg at that speed. The results of the ANOVA are shown in Table 5.

Table 5

Summary of ANOVA for Extension of the Dominant and
Nondominant Legs at 60°/second.

Source	df	SS	Ms	F
Between Measures	1	5055.21	5055.21	*51.32
Residual	49	4826.29	98.50	

$p < .05$

The finding, $F(1, 49) = 51.32$, $p < .05$, lead to the rejection of Null Hypothesis 1b as it relates to extension of the dominant and nondominant legs.

An examination of the results reported in Table 6 shows an analysis of variance score of $F(1, 49) = 3.99$, $p < .05$. This score indicates that there was no significant difference ($p < .05$) between the mean torque values reported for the right ($\bar{x} = 130.86$) and left ($\bar{x} = 126.52$) legs during extension at a speed of 60°/second. On the basis of this finding, the investigator failed to reject Null Hypothesis 1c.

Table 6

Summary of ANOVA for Extension of the Right and Left Legs at 60°/second.

Source	df	SS	Ms	F
Between Measures	1	470.89	470.89	3.99
Residual	49	578.61	118.05	

$p < .05$

Null Hypothesis 2. There will be no significant difference between mean strength of subjects' two legs as measured by peak torque generated during the flexion phase at 60°/second:

- a. preferred vs. nonpreferred (refer to page 44),
- b. dominant vs. nondominant,
- c. right vs. left.

The data reported in Table 7 show a significant difference ($p < .05$) was found to exist between the mean torque value for the dominant leg ($\bar{x} = 84.46$) during flexion at 60°/second and the mean torque value of the nondominant leg ($\bar{x} = 76.60$) at the same speed. The data presented in Table 7 show the results of the analysis of variance as $F(1, 49) = 69.94$, $p < .05$. This finding was the basis for rejecting Null Hypothesis 2b as it relates to the dominant and the nondominant legs.

Table 7

Summary of ANOVA for Flexion of the Dominant and Nondominant
Legs at 60°/second.

Source	df	SS	Ms	F
Between Measures	1	1544.49	1544.49	*69.94
Residual	49	1082.01	22.08	

$p < .05$

This hypothesis was also tested as it related to flexion of the right and left legs at a speed of 60°/second. The mean scores were 81.06 for the right leg and 80.00 for the left. The difference between the two means was not significant ($p < .05$). This statistical analysis ($F(1, 49) = .53$, $p < .05$) is reported in Table 8. Based on this finding, the investigator failed to reject Null Hypothesis 2c as it relates to the right and left legs.

Table 8

Summary of ANOVA for Flexion of the Right and Left Legs at
60°/second.

Source	df	SS	Ms	F
Between Measures	1	28.09	28.09	0.53
Residual	49	2598.41	53.03	

$p < .05$

Null Hypothesis 3. There will be no significant difference between mean strength of subjects' two legs as measured by peak torque generated during the extension phase at 180°/second.

- a. preferred vs. nonpreferred (refer to page 44),
- b. dominant vs. nondominant,
- c. right vs. left.

The mean peak torque score for the dominant leg during the extension phase at 180°/second was 88.84. This was significantly different ($p < .05$) from the score ($\bar{x} = 80.48$) obtained from the nondominant leg at the same speed. Inspection of Table 9 reveals an ANOVA score of $F(1, 49) = 41.79$, $p < .05$. Due to this finding, the investigator must reject Null Hypothesis 3b.

Table 9

Summary of ANOVA for Extension of the Dominant and Nondominant Legs at 180°/second.

Source	df	SS	Ms	F
Between Measures	1	1747.24	1747.24	*41.79
Residual	49	2039.76	41.63	

$p < .05$

The results reported in Table 10 show no significant difference ($p < .05$) exist between the mean torque values for extension of the right ($\bar{x} = 84.34$) and the left ($\bar{x} = 83.82$) legs at a test speed of $180^\circ/\text{second}$. This finding, $F(1, 49) = .15$, $p < .05$, supports the investigator's decision to fail to reject Null Hypothesis 3c.

Table 10

Summary of ANOVA for Extension of the Right and Left Legs at $180^\circ/\text{second}$.

Source	df	SS	Ms	F
Between Measures	1	6.76	6.76	0.15
Residual	49	2270.24	46.33	

$p < .05$

Null Hypothesis 4. There will be no significant difference between mean strength of subjects' two legs as measured by peak torque generated during the flexion phase at 180°/second.

- a. preferred vs. nonpreferred (refer to page 44),
- b. dominant vs. nondominant,
- c. right vs. left.

The results of the analysis of variance, $F(1, 49) = 112.70$, $p < .05$, reported in Table 11, indicated that a significant difference ($p < .05$) exists between the mean scores for flexion of the dominant leg ($\bar{x} = 63.90$) at 180°/second and the nondominant leg ($\bar{x} = 58.26$) at the same speed. This finding supports to the rejection of Null Hypothesis 4b.

Table 11

Summary of ANOVA for Flexion of the Dominant and Nondominant Legs at 180°/second.

Source	df	SS	Ms	F
Between Measures	1	795.24	795.24	*112.70
Residual	49	345.76	7.06	

$p < .05$

An examination of the results reported in Table 12 shows an ANOVA score of $F(1, 49) = .39$, $p < .05$. This score indicates that no significant difference ($p < .05$) exists between the mean peak torque values for the right leg ($\bar{x} = 61.38$) and the values for the left leg ($\bar{x} = 60.78$) for flexion at $180^\circ/\text{second}$. The investigator failed to reject Null Hypothesis 4c on the basis of this finding.

Table 12

Summary of ANOVA for Flexion of the Right and Left Legs at $180^\circ/\text{second}$.

Source	df	SS	Ms	F
Between Measures	1	9.00	9.00	0.39
Residual	49	38249.36	23.10	

$p < .05$

Null Hypothesis 5. There will be no significant difference between mean strength of subjects' two legs as measured by peak torque generated during the extension phase at 240°/second.

The mean peak torque value obtained for the dominant leg ($\bar{x} = 73.34$) for extension at a speed of 240°/second was significantly different ($p < .05$) from the mean values for the nondominant leg ($\bar{x} = 66.80$) at the same speed. The F score reported in Table 13, $F(1, 49) = 79.85$, $p < .05$, was the basis for this finding as well as for the rejection of Null Hypothesis 5b.

Table 13

Summary of ANOVA for Extension of the Dominant and Nondominant Legs at 240°/second.

Source	df	SS	Ms	F
Between Measures	1	1069.29	1069.29	*79.85
Residual	49	656.21	13.39	
$p < .05$				

The results of the analysis of variance reported in Table 14, $F(1, 49) = 1.72$, $p < .05$, show that there is no significant difference between the mean scores for extension of the right leg ($\bar{x} = 70.74$) at $240^\circ/\text{second}$ and the scores reported for the left leg ($\bar{x} = 69.24$) at the same speed. The investigator failed to reject Null Hypothesis 5c on the basis of this finding.

Table 14

Summary of ANOVA for Extension of the Right and Left Legs at $240^\circ/\text{second}$.

Source	df	SS	Ms	F
Between Measures	1	56.25	56.25	1.72
Residual	49	1605.25	32.76	

$p < .05$

Null Hypothesis 6. There will be no significant difference between mean strength of subjects' two legs as measured by peak torque generated during the flexion phase at 240°/second.

- a. preferred vs. nonpreferred (refer to page 44),
- b. dominant vs. nondominant,
- c. right vs. left.

The results related to Null Hypothesis 6 are reported in Tables 15 and 16. The analysis of data reported in Table 15 shows an F value of $F(1, 49) = 67.55$, $p < .05$, which indicates a significant difference ($p < .05$) existed between the mean peak torque scores for flexion of the dominant leg ($\bar{x} = 56.26$) at 240°/second and the scores for the nondominant leg ($\bar{x} = 50.88$) at the same speed. Based on this finding, Null Hypothesis 6b was rejected.

Table 15

Summary of ANOVA for Flexion of the Dominant and Nondominant Legs at 240°/second.

Source	df	SS	Ms	F
Between Measures	1	723.61	723.61	*67.55
Residual	49	524.89	10.71	
$p < .05$				

Table 16

Summary of ANOVA for Flexion of the Right and Left Legs at
240°/Second.

Source	df	SS	Ms	F
Between Measures	1	19.36	19.36	0.87
Residual	49	1089.64	22.24	

$p < .05$

The result of the analysis of variance, $F(1, 49) = .87$, $p < .05$, reported in Table 16 indicates that no significant difference ($p < .05$) existed between the mean peak torque values for flexion of the right leg ($\bar{x} = 53.90$) at 240°/sec. and the values for the left leg ($\bar{x} = 53.02$) at the same speed. This finding lead to the investigator's decision to fail to reject Null Hypothesis 6c.

In summary, a comparison of the mean peak torque scores for extension and flexion of the dominant and nondominant legs at speeds of 60°, 180°, 240°/second produced statistically significant ($p < .05$) F values for each pair of the means analyzed. The results of these comparisons strongly suggested that preparticipation and preinjury differences do exist between legs. This is particularly evident when the strength level of each leg is examined on a subject by subject basis or when group comparisons are made between the

subjects' stronger legs and their weaker legs. These findings agreed with those of Goslin and Charteris (1979).

When the mean peak torque values for extension and flexion of the right and left legs were compared under the same conditions as the dominant and the nondominant legs, no significant differences ($p < .05$) were found. The results of Goslin and Charteris (1979) study also supported these findings. Garzione and Marrifield (1979), however, found a significant difference between the right and left legs during flexion.

The investigator believes that any strength differences that may have been present between the right and left legs were negated by a chance mixing of the peak torque scores of the subjects' strong and weak legs. Thus, the comparison of the means derived from these scores produced no significant ($p < .05$) F values.

Of the 50 subjects tested, 46 preferred to use their right legs to kick a ball. This finding, in conjunction with the results reported above, indicated that the strong leg and the preferred leg were not necessarily the same for each individual tested. This would suggest the need for a universal definition of the terms dominant and nondominant, as well as preferred and nonpreferred. Wyatt and Edwards (1981) and Holmes and Alderink (1984) concurred with this suggestion.

CHAPTER V

APPLICATION OF ACQUIRED KNOWLEDGE

The purpose of this study was to apply computerized isokinetic function and measurement to physical education instruction. In the process of formulating this study and reporting its results, this researcher has gained some insight into applying what has been learned. These new understandings which are related to both the process and the product of this investigation are the basis for the brief discussion which follows.

One way of assessing the value of any research experience is to examine its outcomes in light of their potential for practical application. Since the investigator's primary area of interest is in curriculum and instruction, it seemed appropriate to discuss these outcomes as they relate to components of physical education.

The four discussion topics identified in Chapter I (Statement of the Purpose of the Study), while not all inclusive, are representative of the practical applications to which the outcomes of this study could contribute.

Training

Generally, it is believed among physical educators, trainers, medical professionals, coaches, and athletes, that an increase in muscle strength will result in an increase in physical fitness and, therefore, the basis for an athlete's performance will also be increased (Burke, 1978).

An isokinetic instrument, such as the one used in this study, can be an effective training device for improving muscle function in specific areas of weakness. This device not only allows the accurate, objective measurement of muscle function during preseason screening and evaluation, but it allows trainers to closely monitor the athlete's progress during a strength development program (Lesmes, Costill, Coyle & Fink, 1978).

Individual athletes who have a particular injury potential due to muscular weaknesses can be assigned to a special isokinetic strengthening exercise program to develop and maintain equitable strength levels in both left and right limbs and at different performance speeds (Mannis, 1980).

In using the isokinetic system as a training model, athletic trainers and physical therapists should consider the following principles when planning a strength conditioning program:

1. The program should be tailored to the individual athlete.

2. A specific pattern of exercise, speed, repetition, and duration should be chosen.

3. A functional speed should be selected in order to increase muscle strength in a functional range.

4. Muscle strength should develop first, then power and endurance.

5. The overload principle must be applied, i.e., increase frequency, intensity, and duration.

6. A training speed must be chosen which will overload the muscle without leading to complete exhaustion.

7. Strength training should be performed throughout the entire range motion (Klafs & Arnheim, 1981).

The results reported in Chapter IV of this study suggest that these principles must be applied equally to collateral limbs if peak performances and a reduction of injuries are to be expected.

Measurement and Evaluation

The purpose of pretesting using the isokinetic system is to create an objective profile record of muscle strength levels to act as baseline documentation in such activity oriented areas as sports and industry. This data can play an important role in training prescription, injury diagnosis, job classification, and progressive rehabilitation.

The literature on this topic indicates that pre-participation and preinjury data is often not available; therefore, judgments must be made with less than adequate

information. This void in the measurement and evaluation process is an area that physical educators and medical professionals must eliminate by including these test protocols in existing instructional programs.

In addition to the related literature, the results of this study support the need for a strength pretesting program. In each instance, it was found that the dominant leg was significantly stronger than the nondominant leg. Interestingly enough this finding is not widely accepted among medical professionals, which reinforces the need for the collection of baseline data and the inclusion of such protocols in the educational programs.

Instruction

Ideally, an instructional aid is important in the teaching-learning environment when it contributes directly to the instructional input of the educational setting.

The most effective method of teaching athletic training, physical education, and physical therapy is to provide preprofessionals with adequate instructional aides such as a wide range of supplies, materials, and equipment during their classroom work, rotating practicums, and clinical experiences.

The isokinetic system can be used as an instructional tool in connection with selected program objectives and course content; for example, in physical therapy, physical education, and athletic training it could be used to assist

student-trainers in utilizing their past experiences in new situations, working with new equipment, while reinforcing the learning process. It can also be used to demonstrate clinical and research procedures related to the assessment and development of muscular strength, endurance, and power. Student-trainers can practice their skills and techniques in applying many theoretical principles related to rehabilitation, treatment, training, and diagnosis.

In learning how to operate a computerized isokinetic system as a prerequisite to conducting this study, this investigator now possesses the skills necessary to use the system as a clinical device, and an instructional tool, and as a research instrument. In addition, and perhaps more importantly, he can teach others to use the system in each of these areas.

Rehabilitation

Generally, in current clinical practice, orthopedic surgeons, physical therapists, and other medical professionals are utilizing the uninjured limb as a model or criterion reference in the rehabilitation process. The aim is to develop the peak torque generated by the rehabilitated limb to a level that is approximately 80% to 85% of that generated by the uninjured limb (Wyatt & Edward, 1981).

The logic of this practice appears sound in theory, however, based on the results presented in this study, it would seem open to question. For example, if the weaker or

nondominant limb is the uninjured limb, the rehabilitation process may prove inadequate, thus an individual may return to strenuous activity with the rehabilitation process only 80% to 85% completed.

The only way to completely avoid this situation is to establish a preinjury profile on each individual. This is of course, difficult, if not impossible to accomplish. Therefore, based on the results of this study, the investigator suggests that the injured leg be rehabilitated to as close to 100% of the strength of the uninjured leg as possible. As more preinjury and rate of recovery data are collected, perhaps another means can be devised to determine which leg was injured, the weaker or the stronger, and thus the appropriate strength level can be predicted (Sherman et al., 1981).

If after further investigation the results of this study are replicated, current clinical, instructional, and research practices should be modified to reflect the conclusions reached in this investigation.

CHAPTER VI SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Summary

The purpose of this study was to apply computerized isokinetic functions and measurements to physical education instruction.

The major research objective of this study was to compare the right and left legs of normal college age subjects for peak torque generated during extension and flexion at three functional speeds. These comparisons were made in an attempt to determine if preparticipation or preinjury differences existed between the preferred leg and the nonpreferred leg, the dominant (stronger) leg and nondominant (weaker) leg, and the right leg and the left leg.

Generally, in current clinical and instructional settings, physical educators, orthopedic surgeons, physical therapists, and other medical professionals are utilizing the uninjured limb as a model or criterion reference in the rehabilitation process. In order to validate this practice, the investigator believed it would be necessary to determine if preinjury difference existed between limbs. If such

differences were found to be present, serious questions would be raised as to the feasibility of such a practice.

The ambivalence of the research findings in this area of investigation lends additional support for the need for a study of this type.

The subjects for this study were selected from the students enrolled in the spring term at the University of Florida. The data were obtained from 50 male and female subjects, ranging in age from 18 to 29 years with a mean age of 22.38 years.

The data for the male and female subjects were combined for analysis based on the results of a pilot study in which no significant difference ($p < .05$) was found between the mean differences for the right and left legs of the male and female subjects. These findings are supported in the literature.

On the day of testing, the subjects completed a subject information sheet to provide a brief medical history. The history noted any injury to the knee, hip, ankle, or back. Limb preference was determined by requiring the subject to kick a ball a distance of four to five feet. The condition of the heart and blood pressure was noted. The subject's weight and height were recorded. Strength data were obtained from subject's right and left legs during extension and flexion at three speeds, i.e., $60^\circ/\text{second}$, $180^\circ/\text{second}$, and $240^\circ/\text{second}$.

A computerized version of the Cybex II (Lumex, Corp., Ronwonkowa, NY) isokinetic dynamometer system and a single channel chart recorder were used in this study to measure muscle strength on both lower extremities of each subject. This device recorded torque in foot-pounds.

A randomized block design analysis of variance (ANOVA) was calculated by using an IBM 360 computer and the SPSSP statistical package. A 2 (right and left) x 3 (speed) x 50 (subject) design was used. Significance was accepted at the $p < .05$ level.

The results of the study showed the peak torque generated by the dominant (stronger) leg was significantly greater ($p < .05$) than that generated by the nondominant (weaker) leg at 60°, 180°, and 240°/second. When the subjects' test results were classified by right and left legs, there was no significant difference ($p < .05$) between the mean scores.

Each of the following represents a potential area of application for the results of this study.

1. The development of a training regimen that maintains equity between the strength of the legs.
2. The establishment of a preparticipation and preinjury testing protocol that provides baseline data for comparison with results of test conducting during and at the completion of training and rehabilitation programs.

3. The development of instructional programs related to the use of the isokinetic dynamometer for clinical, instructional, and research purposes.

4. The establishment of a criterion reference by which the optimum level of rehabilitation of an injured knee joint can be judged objectively.

Conclusions

In this study, the right and left legs of normal college age subjects were compared for peak torque generated during extension and flexion at 60°, 180°, and 240°/second. Based on the results, the following conclusions appeared warranted.

1. The peak torque generated by the dominant leg is significantly greater than that of the nondominant leg during extension and flexion at 60°, 180°, and 240°/second.

2. There is no significant difference between the amount of peak torque generated by the right and left legs during extension and flexion at 60°, 180°, and 240°/second.

3. The preferred leg is not necessarily the strongest leg.

4. It appears that preparticipation and preinjury strength differences do exist between legs.

Recommendations

The preceding conclusions appear to support the following recommendations.

1. Baseline preparticipation and preinjury data should be collected on individuals whenever possible.

2. If the uninjured leg is used as a model or criterion reference to establish a level of rehabilitation for the injured leg, the investigator recommends that the strength goal be set at 100% parity.

3. In order to reduce the confusion among researchers, as well as practitioners regarding the use of the terms dominant and nondominant when referring to the leg, the investigator suggests that the terms preferred and nonpreferred be used to define usage and that dominant and nondominant be used when referring to strength and weakness.

4. The investigator suggests that this study be replicated and if the findings are supported, that instructional programs, as well as clinical and research procedures be altered to accommodate the information that has been generated.

5. It is also recommended that other studies be conducted on related topics, e.g. examining torque ratios between quadriceps and hamstrings for optimal and safe performance, establishing baseline data for children and older adults, studying other joints of the body, etc.

APPENDIX A
LETTER OF APPROVAL

January 25, 1985

TO: Mr. Mustafa Hayat
303 FLG

FROM: C. Michael Levy, Chair,
University of Florida Institutional
Review Board

SUBJECT: Approval of Project # 85-27
A COMPARISON OF CYBEX MEASUREMENTS BETWEEN THE
RIGHT AND LEFT LEGS OF COLLEGE AGE STUDENTS

Your request for approval for a project involving human subjects, referenced above, is approved as recommended by the University of Florida Institutional Review Board. The Board has concluded that subjects are not placed at risk in the approved project. Given your protocol, however, it is essential that you obtain written informed consent from each participant. You are reminded that any change in the protocol for this project must be submitted to the Board for consideration before it is implemented. In addition, you are obliged to report to this Board any unexpected complications arising from the project which affect your subjects.

If the project has not been completed by January 25, 1986, please telephone our office (2-0433) and request instructions for obtaining a renewal of this approval.

By a copy of this memorandum, your department Chair is reminded that he is responsible for being informed about the status of all projects involving human subjects in your department, and for reviewing the protocol of such projects as often as necessary to insure that each project is being conducted in the manner approved by this memorandum.

CML/her

cc: Dr. Robert E. Allen, 303 FLG
Dr. O. J. Holyoak, 301 FLG
Dr. Clifford Boyd, 203 FLG
Ms. Kate Phillips, 211 GRI

APPENDIX B
INFORMED CONSENT

Informed Consent

The purpose of this study is to compare the strength, power, and power endurance levels of the right and left legs of normal subjects.

The data will be collected using the Cybex II isokinetic system with which you are familiar. You will be seated and stabilized with the axis of the knee aligned with the axis of the dynamometer shaft. Starting at approximately 105 degrees of knee flexion, you will move the leg to full extension and then return to the starting position. This procedure will be repeated four or five times at each of three preset speeds of 60, 180, and 240 degrees per second for each leg. Based on this data, a dominate leg will be identified and comparisons will be made with the nondominate leg.

You can expect mild discomfort to be associated with the vigorous movement of the leg, however, this is normal and poses little or no risk to you. Any discomfort you experience should be dissipated quickly since the exercise portions of the procedure each take only a few seconds.

The investigator will be happy to answer any questions you might have regarding this study. Further, you should understand that you are free to withdraw your consent and to discontinue your involvement in this project at any time without prejudice and that no monetary compensation will be awarded to you for your participation.

"I understand that if I am injured during this study, and if the investigator is at fault, the University of Florida and the Board of Regents of the State of Florida shall be liable only as provided by law. I understand that I may seek appropriate compensation for injury by contacting the Insurance Coordinator at 107 Tigert Hall, University of Florida, telephone number 392-1325."

"I have read and I understand the procedure described above. I agree to participate in the procedure and I have received a copy of this description."

Signatures:

Subject	Date	Witness	Date
Relationship if other than subject	Date	Principal Investigator's name	Date

2901 Apt. 233 SW 13th St.
Gainesville, FL 32608
Mustafa Hayat

APPENDIX C

RAW STRENGTH SCORES FOR RIGHT AND LEFT LEGS

Raw Strength Scores*

Right Leg

Left Leg

Sub- ject #	Extension			Flexion			Extension			Flexion		
	60%	180%	240%	60%	180%	240%	60%	180%	240%	60%	180%	240%
1	80	55	50	61	44	46	105	69	55	51	46	38
2	95	59	45	60	41	27	90	55	48	62	50	41
3	175	112	100	76	66	61	160	114	97	79	70	62
4	104	64	54	55	40	38	121	70	61	62	45	39
5	165	113	108	105	84	78	140	117	101	109	87	70
6	139	99	83	92	71	57	134	97	84	83	76	64
7	203	124	110	129	92	77	168	129	104	120	87	77
8	132	100	82	92	75	68	137	99	84	100	80	71
9	197	126	112	101	74	66	161	115	103	92	75	70
10	200	140	117	116	83	73	173	120	108	110	79	75
11	141	95	82	99	87	86	140	96	79	122	95	87
12	227	125	117	158	108	102	218	146	116	126	113	93
13	120	76	63	71	51	40	129	77	68	74	51	39
14	82	55	48	47	35	29	80	51	39	36	31	27
15	181	126	108	116	90	80	162	132	121	110	83	70
16	137	92	83	87	78	66	120	88	61	87	70	68
17	104	68	60	75	57	51	104	69	56	82	64	58
18	99	61	49	45	26	10	100	55	46	52	17	10
19	102	57	47	61	38	29	101	63	47	66	46	44
20	116	68	58	69	46	39	113	65	56	75	50	43
21	116	84	70	67	50	40	89	67	59	73	53	49
22	181	105	72	115	75	57	147	99	84	107	71	60
23	126	77	67	76	52	47	132	80	65	72	48	44
24	133	95	72	92	72	57	125	98	78	72	62	50
25	75	48	36	64	48	39	83	59	49	59	40	35
26	121	86	73	52	45	41	98	75	59	58	50	46
27	148	103	76	85	63	62	153	104	77	107	73	58

Left Leg

Right Leg

Sub- ject #	Extension			Flexion			Extension			Flexion		
	60°	180°	240°	60°	180°	240°	60°	180°	240°	60°	180°	240°
28	114	94	75	80	66	55	103	91	72	90	83	68
29	189	120	100	112	91	85	162	131	111	126	87	76
30	118	81	70	97	68	62	113	58	50	77	53	49
31	111	68	56	56	54	50	123	74	57	65	53	43
32	101	64	54	66	51	46	102	58	39	67	50	41
33	198	122	101	117	84	77	202	107	101	121	74	79
34	110	68	53	66	49	41	122	78	66	60	44	38
35	158	108	90	71	50	49	187	111	86	84	57	48
36	153	90	73	86	67	57	148	95	72	78	52	46
37	67	41	35	50	38	31	66	38	33	44	34	31
38	116	66	55	60	46	42	101	59	43	63	45	41
39	95	58	49	50	31	30	93	60	53	47	39	32
40	111	68	57	80	55	53	102	61	56	62	51	45
41	98	62	51	60	42	37	89	53	42	56	41	34
42	69	37	29	56	40	31	85	39	33	55	35	31
43	142	100	79	93	77	67	155	106	86	93	76	64
44	140	76	57	95	78	71	142	84	62	94	74	61
45	154	100	84	112	76	68	135	94	73	96	75	70
46	101	62	58	84	50	49	113	66	53	64	47	39
47	73	55	41	59	54	36	80	35	35	53	44	36
48	115	87	62	61	52	43	98	74	59	66	58	50
49	195	110	101	125	108	104	190	128	106	122	100	92
50	116	67	65	73	51	45	132	82	69	71	55	49

*Scores expressed in Foot-Pounds

APPENDIX D

RAW STRENGTH SCORES FOR DOMINANT AND NONDOMINANT LEGS

Raw Strength Scores*

Sub- ject #	Dominant Leg			Nondominant Leg		
	Extension	Flexion		Extension	Flexion	
1	105	69	55	46	61	46
2	160	114	48	50	62	51
3	175	114	100	70	79	60
4	121	70	61	45	62	97
5	165	117	108	87	109	54
6	139	99	84	92	92	101
7	203	129	110	76	105	84
8	137	100	84	77	104	83
9	197	126	100	92	102	87
10	200	140	112	80	104	77
11	141	96	116	75	103	75
12	227	146	122	83	115	92
13	129	77	158	95	120	74
14	82	55	74	102	108	66
15	181	132	48	35	116	87
16	137	92	83	51	125	93
17	104	69	60	80	126	108
18	100	61	49	29	71	51
19	102	63	47	39	82	31
20	116	68	58	36	92	27
21	116	84	70	108	110	70
22	181	105	84	87	87	66
23	132	80	67	61	56	51
24	133	98	78	56	75	57
25	83	59	49	45	45	17
26	121	86	73	47	61	38
27	153	104	77	57	69	29
				59	46	39
				72	50	40
				107	71	57
				72	48	44
				65	72	44
				72	62	50
				72	45	35
				59	40	41
				52	45	41
				76	63	58

Sub-
ject #

60% 180% 240% 60% 180% 240% 60% 180% 240%

1	105	69	55	46	61	46	80	55	50	51	44	38
2	160	114	48	50	62	41	95	59	45	60	41	27
3	175	114	100	70	79	62	160	112	97	76	66	61
4	121	70	61	45	62	39	104	64	54	55	40	38
5	165	117	108	87	109	78	140	113	101	105	84	70
6	139	99	84	92	92	64	134	97	83	83	71	57
7	203	129	110	76	105	77	168	124	104	102	87	77
8	137	100	84	92	100	71	132	99	82	92	75	68
9	197	126	100	80	101	70	161	115	103	92	74	66
10	200	140	112	75	103	75	173	120	108	110	79	73
11	141	96	116	83	110	87	140	95	79	99	87	87
12	227	146	122	95	125	102	218	125	116	126	108	93
13	129	77	158	113	120	40	120	76	63	71	51	39
14	82	55	74	51	80	29	80	51	39	36	31	27
15	181	132	48	35	116	80	162	126	108	110	83	70
16	137	92	83	90	88	68	120	88	61	87	70	66
17	104	69	60	64	58	58	104	68	56	75	57	51
18	100	61	49	26	10	46	99	55	46	45	17	10
19	102	63	47	46	44	44	101	57	47	61	38	29
20	116	68	58	50	43	43	113	65	56	69	46	39
21	116	84	70	53	49	49	89	67	59	67	50	40
22	181	105	84	75	60	60	147	99	72	107	71	57
23	132	80	67	52	47	47	126	77	65	72	48	44
24	133	98	78	72	57	57	125	95	72	72	62	50
25	83	59	49	48	39	39	75	48	36	59	40	35
26	121	86	73	50	46	46	98	75	59	52	45	41
27	153	104	77	73	62	62	148	103	76	85	63	58

Nondominant Leg

Dominant Leg

Sub- ject #	Extension			Flexion			Extension			Flexion		
	60%	180%	240%	60%	180%	240%	60%	180%	240%	60%	180%	240%
28	114	94	75	90	83	68	103	91	72	80	66	55
29	189	131	111	126	91	85	162	120	100	112	87	76
30	118	81	70	97	68	62	113	58	50	77	53	49
31	123	74	57	65	54	50	111	68	56	56	53	43
32	102	64	54	67	51	46	101	58	39	66	50	41
33	202	122	101	121	84	79	198	107	101	117	74	77
34	122	78	66	66	49	41	110	68	53	60	44	38
35	187	111	90	84	57	49	158	108	86	71	50	48
36	153	95	73	86	67	57	148	90	72	78	52	46
37	67	41	35	50	38	31	66	38	33	44	34	31
38	116	66	55	63	46	42	101	45	43	60	45	41
39	95	60	53	50	39	32	93	58	49	47	31	30
40	111	68	57	80	55	53	102	61	56	62	51	45
41	98	62	51	60	42	37	89	53	42	56	41	34
42	85	39	33	56	40	31	69	37	29	55	35	31
43	155	106	86	93	77	67	142	100	79	93	76	64
44	142	84	62	95	78	71	140	76	57	94	74	61
45	154	100	84	112	76	70	135	94	73	96	75	68
46	113	66	58	64	50	49	103	62	53	62	47	39
47	80	55	41	59	54	36	73	53	35	53	44	36
48	115	87	62	66	58	50	98	74	59	61	52	43
49	195	128	106	125	108	104	190	110	101	122	100	92
50	132	82	69	73	55	49	116	67	65	71	51	45

*Scores expressed in Foot-Pounds

APPENDIX E

SAMPLE OF CYBEX DATA REDUCTION PRINT-OUTS


```

1 TORQUE TESTS
2 REPEAT EACH
3 40 DEL/SEC
4 120 DEL/SEC
5 240 DEL/SEC (1) WORK
6 WORK TEST
7 15 TOTAL REPS AND
8 SAMPLE REPS EACH
9 40 DEL/SEC

```

RIGHT SIDE DATA

```

EXTENSION
101  *TABS = 56 DEG
102  *BEAKING RATIO

```

```

FLEXION
22 FT-LES = 22 253
40# BREAKDOWN RATIO
FLEXION/EXTENSION
21# PEEKS

```

MAX PGM TESTED
21 DEG 5 DEG

RIGHT SIDE DATA

EXTENSION
62 FT-LBS = 26 CEB
42: PEAK:SL RATIO

EXTENSION
TO FT-101 - 27 DEC
10: PEAKS/BIN RATIO
EXTENSION/EXTENSION
BIN: PEAKS

RIGHT SIDE DATA
-EST :
240 DEG/SEC 12 2203

EXTENSION
89 FT-LBS = 42 C-83
NEW PEAKING RATIO

FLEXION
43 FT-LBS = 29 DEG
22% PEAK:NBW RATIO
FLEXION:EXTENSION
64% PEAKS

MAX ROM TESTED
24 DEC 80 DEC

WORK AT 240 DEG/SEC

```

EXTENSION
13 39 FT-LBS PK TAB
798 FT-LBS 12 REFS
122 FT-LBS 1ST "
120 FT-LBS LAST "
TAB ENCOURANCE RATIO
32 DEG AVG POW
134 WATTS AVG POW

```

ELEVON
OK TBE
ENDURANCE RATIO
CSD AVG ROM
WATS AVG POW

ELUTION FRACTIONATION
WATER RATIO = 1:1

[illegible]

EXTENSION
 44-38861-1000
 1000

FLEXION
54 FT-LBS * 28 DEG
41% BREAKAWAY RATIO
FLEXION/EXTENSION
8-11 DEGS

NA.	ROM	TESTED
13	CEG	12
		CEG

[illegible]

EXTENSION
46. ST-USE = 47. CEE
48. PEAKISH RATIO

```

FLEXION
47 FT LBS = 20.880
40% BREAKING RATIO
FLEXION/EXTENSION
PEAKS

```

MAX ROM TESTED
36 DEG 9 DEG

TEST CODE DATA
TEST
243 ONLY TEST 18 DEPT

EXTENSION
55 FT-LBS = 45 DEG
24% PEAKING RATIO

```

      FLEXION
      ST-UBS = 45 DEG
      PERKINOW RATIO
      FLEXION/EXTENSION
      PERKS

```

MAX POW TESTED
27 DEG 9 DEG

WORK AT 240 DEG/SEC

EXTENSION	
44	RT-105 0K 00
45	RT-105 10 00
46	RT-105 20 00
47	RT-105 30 00
48	RT-105 40 00
49	RT-105 50 00
50	RT-105 60 00
51	RT-105 70 00
52	RT-105 80 00
53	RT-105 90 00
54	RT-105 00 00
55	RT-105 10 00
56	RT-105 20 00
57	RT-105 30 00
58	RT-105 40 00
59	RT-105 50 00
60	RT-105 60 00
61	RT-105 70 00
62	RT-105 80 00
63	RT-105 90 00
64	RT-105 00 00
65	RT-105 10 00
66	RT-105 20 00
67	RT-105 30 00
68	RT-105 40 00
69	RT-105 50 00
70	RT-105 60 00
71	RT-105 70 00
72	RT-105 80 00
73	RT-105 90 00
74	RT-105 00 00
75	RT-105 10 00
76	RT-105 20 00
77	RT-105 30 00
78	RT-105 40 00
79	RT-105 50 00
80	RT-105 60 00
81	RT-105 70 00
82	RT-105 80 00
83	RT-105 90 00
84	RT-105 00 00
85	RT-105 10 00
86	RT-105 20 00
87	RT-105 30 00
88	RT-105 40 00
89	RT-105 50 00
90	RT-105 60 00
91	RT-105 70 00
92	RT-105 80 00
93	RT-105 90 00
94	RT-105 00 00
95	RT-105 10 00
96	RT-105 20 00
97	RT-105 30 00
98	RT-105 40 00
99	RT-105 50 00
00	RT-105 60 00
01	RT-105 70 00
02	RT-105 80 00
03	RT-105 90 00
04	RT-105 00 00
05	RT-105 10 00
06	RT-105 20 00
07	RT-105 30 00
08	RT-105 40 00
09	RT-105 50 00
10	RT-105 60 00
11	RT-105 70 00
12	RT-105 80 00
13	RT-105 90 00
14	RT-105 00 00
15	RT-105 10 00
16	RT-105 20 00
17	RT-105 30 00
18	RT-105 40 00
19	RT-105 50 00
20	RT-105 60 00
21	RT-105 70 00
22	RT-105 80 00
23	RT-105 90 00
24	RT-105 00 00
25	RT-105 10 00
26	RT-105 20 00
27	RT-105 30 00
28	RT-105 40 00
29	RT-105 50 00
30	RT-105 60 00
31	RT-105 70 00
32	RT-105 80 00
33	RT-105 90 00
34	RT-105 00 00
35	RT-105 10 00
36	RT-105 20 00
37	RT-105 30 00
38	RT-105 40 00
39	RT-105 50 00
40	RT-105 60 00
41	RT-105 70 00
42	RT-105 80 00
43	RT-105 90 00
44	RT-105 00 00
45	RT-105 10 00
46	RT-105 20 00
47	RT-105 30 00
48	RT-105 40 00
49	RT-105 50 00
50	RT-105 60 00
51	RT-105 70 00
52	RT-105 80 00
53	RT-105 90 00
54	RT-105 00 00
55	RT-105 10 00
56	RT-105 20 00
57	RT-105 30 00
58	RT-105 40 00
59	RT-105 50 00
60	RT-105 60 00
61	RT-105 70 00
62	RT-105 80 00
63	RT-105 90 00
64	RT-105 00 00
65	RT-105 10 00
66	RT-105 20 00
67	RT-105 30 00
68	RT-105 40 00
69	RT-105 50 00
70	RT-105 60 00

```

      FLEXION
    0.6 ST-BS BK "AS
    0.7 TT-BUS LA BEPS
    0.8 TT-BUS LST
    .9 ST-LBS LAST
    ENDURANCE RATIO
    .4 DBL AVG ROM
    .8 WATTS AVG POW
```

한글: 2008년 12월 15일

LEFT/RIGHT DEBITS

EXTENSION
TORQ AT 90 DEG, SEC
-1.00 EPC PERK E

-27 OCT PERKS
 -28 OCT PERKS

EXTENSION
TORG AT 1200 051 JEC

59.2 OPGT PEEKS
FLEXION
TORQ AT 190 DEG/SEC
5% OPGT PEEKS

EXTENSION
TORQ AT 240 DEG/SEC:

FLEXION
 TORQUE AT 240 CM: 35.0
 20% BEST 25KGS

EXTENSION
WORK PT 240 252 253
1500 1507 25 258

```

1.2.10 DFCY TOT 40PK
1.2.10 DFCY AVG 70W
      FLEXION

```

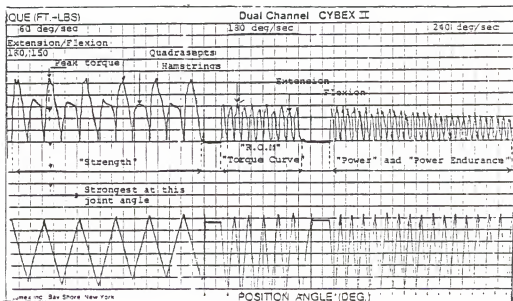
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AGPK AT 240 CBN/2B:
177: OFCT PK TAE
187: OFCT TOT AGRX
197: OFCT AVG POM

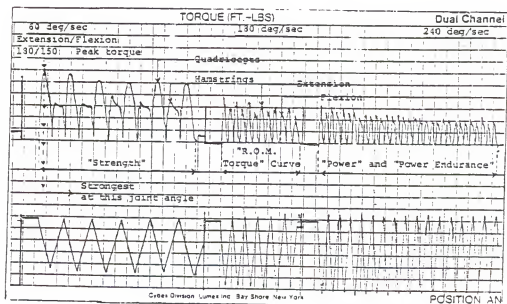
```

APPENDIX F

SAMPLE OF DUAL-CHANNEL RECORDER PRINT-OUTS



Extension/Flexion of right leg



Extension/Flexion of left leg

APPENDIX G

PERMISSION LETTER FROM CYBEX, A DIVISION OF LUMEX, INC.



2100 SMITHTOWN AVENUE, RONKONKOMA, NEW YORK 11779 • (516) 585-9000
TWX 510 228 7198 CYBEX RKNK • CABLE CYBEX RKNK RONKONKOMANY

May 31, 1985

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Authorized Signature



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BIOGRAPHICAL SKETCH

Mustafa A. Jowher Hayat was born on October 1, 1946, in the State of Kuwait. He received his teaching certification in physical education from the Kuwait Teaching Institute in 1967. In July 1977, he graduated with a bachelor's degree from the University of Hulwan, Egypt.

Mr. Hayat taught Physical Education at an elementary school for four years, for four years at a secondary school, and for two years at a high school. He is also a referee member of the Federation of International Gymnastics (FIG), and Kuwait Handball Team Association.

In January 1980, Mr. Hayat enrolled in the Graduate School of the University of Florida in the Department of Professional Physical Education, and in August 1981, he received his Master of Arts in Physical Education.

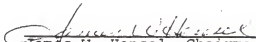
In September 1981, he started his studies at the University of Florida's College of Education where he began work on his PhD in curriculum and instruction with a specialization vocational education-health related professions.

Mr. Hayat is a member of the Kuwait Teaching Association, The American Alliance for Health, Physical Education, Recreation, and Dance. The American College of Sports

Medicine. The National Athletic Trainer's Association, and, Phi Delta Kappa, a scholastic honor society.

Mustafa A. Jowher Hayat has been married since 1970, and he is the father of two daughters and one son. His permanent address is State of Kuwait, Al-Salmiya, P.O. Box 8867.

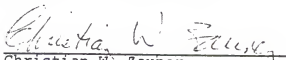
I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.


James W. Hensel, Chairman
Professor of Educational
Leadership

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This dissertation was submitted to the Graduate Faculty of the College of Education and to the Graduate School, and was accepted as partial fulfillment of the requirements for the degree of Doctor of Philosophy.

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